Physical and Computational Modeling of Heat Transfer for Titan Montgolfier Balloons

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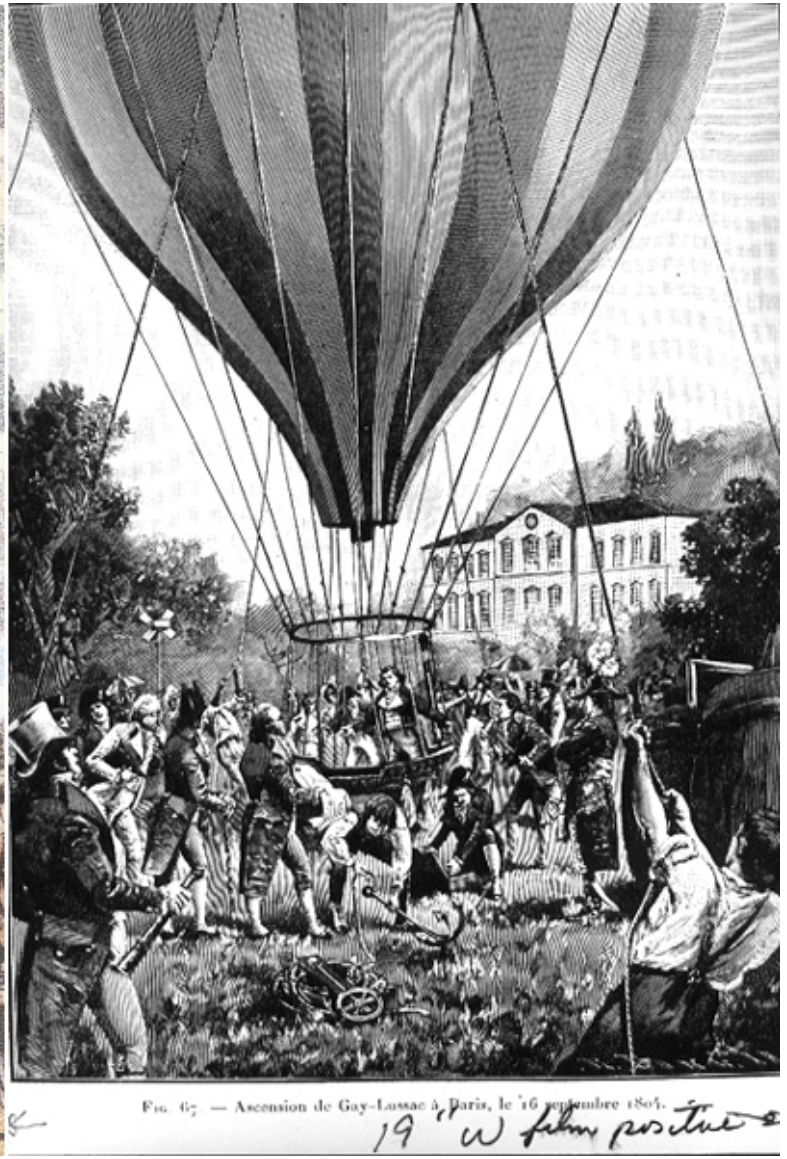
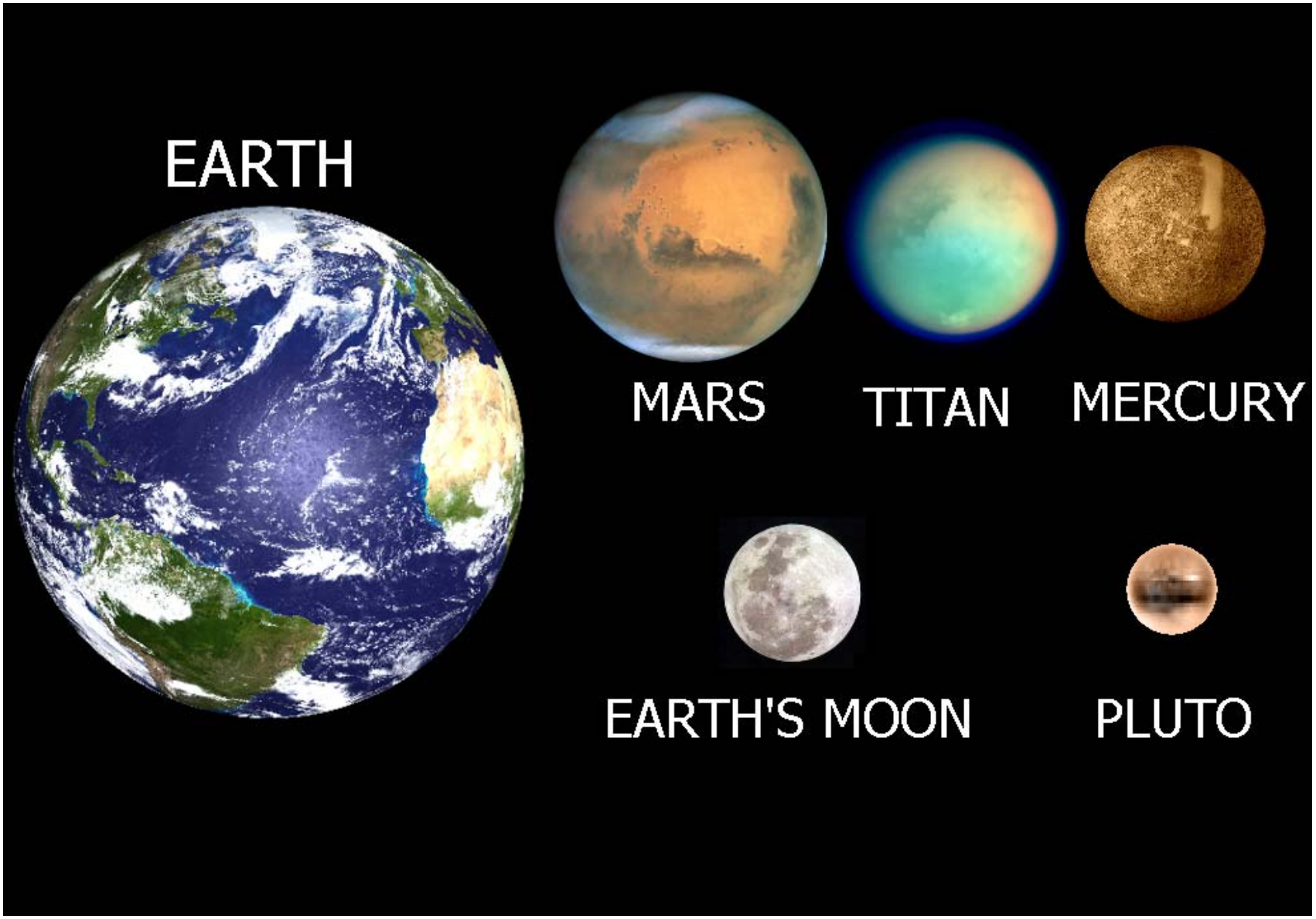
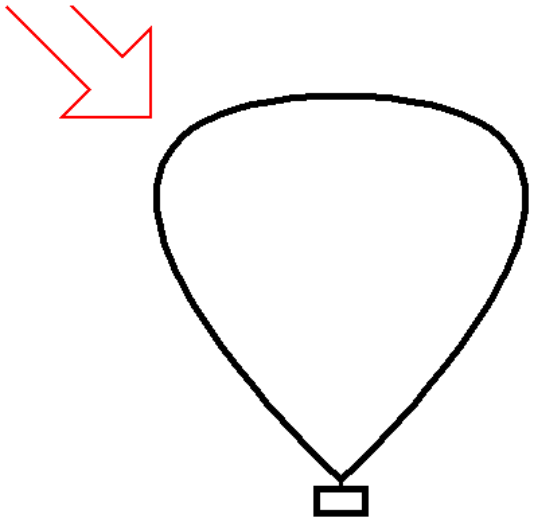
Why balloons?



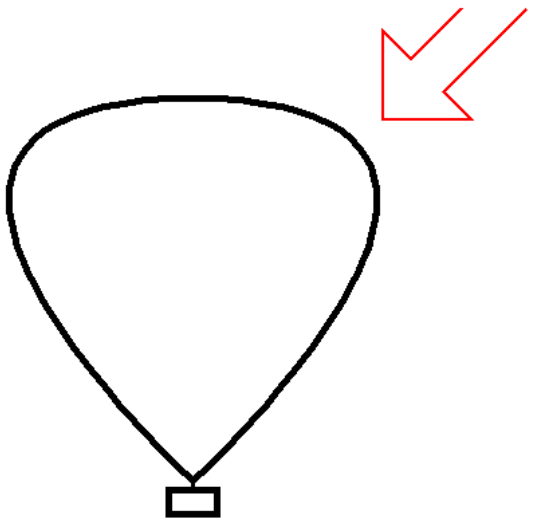
Why balloons for Titan?



SOLAR HEAT 1,000
TIMES LESS.

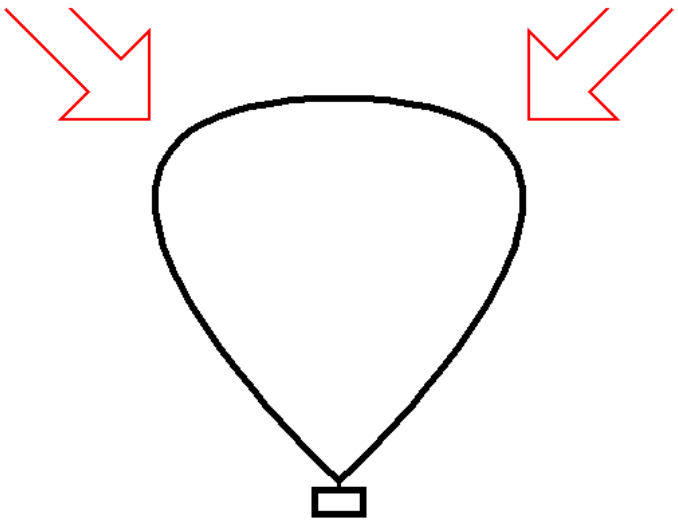


ULTRAVIOLET > 1,000
TIMES LESS.



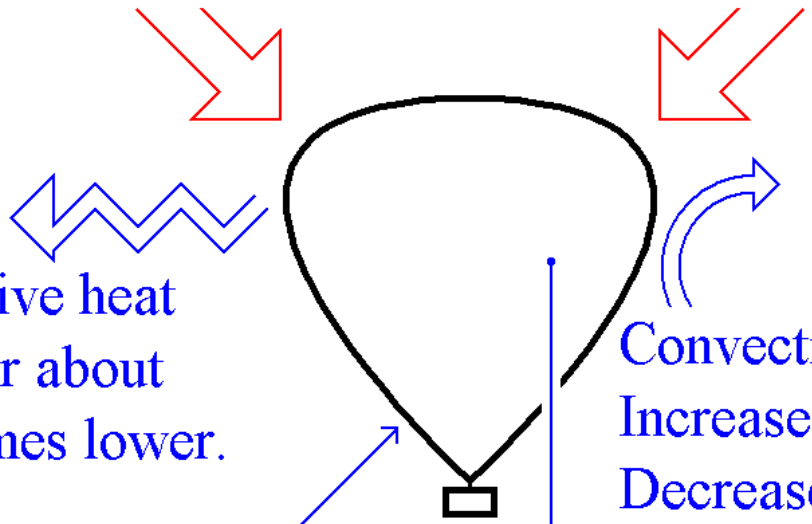
SOLAR HEAT 1,000 TIMES LESS.

ULTRAVIOLET > 1,000 TIMES LESS.



SOLAR HEAT 1,000 TIMES LESS.

ULTRAVIOLET > 1,000 TIMES LESS.



Radiative heat transfer about 100 times lower.

Convection: Increased by density. Decreased by low gravity.

Fabric coating very cold: diffusion many orders of magnitude less. But pinhole formation problems greater.

High density and low temperature: lift about 15 times greater for a given temperature rise.

VERY LOW TEMPERATURE
VERY HIGH DENSITY
LOW GRAVITY

Why a Montgolfiere?

Why convection?

ANITA over the
South Pole
December 2006

Montgolfier balloon radiation

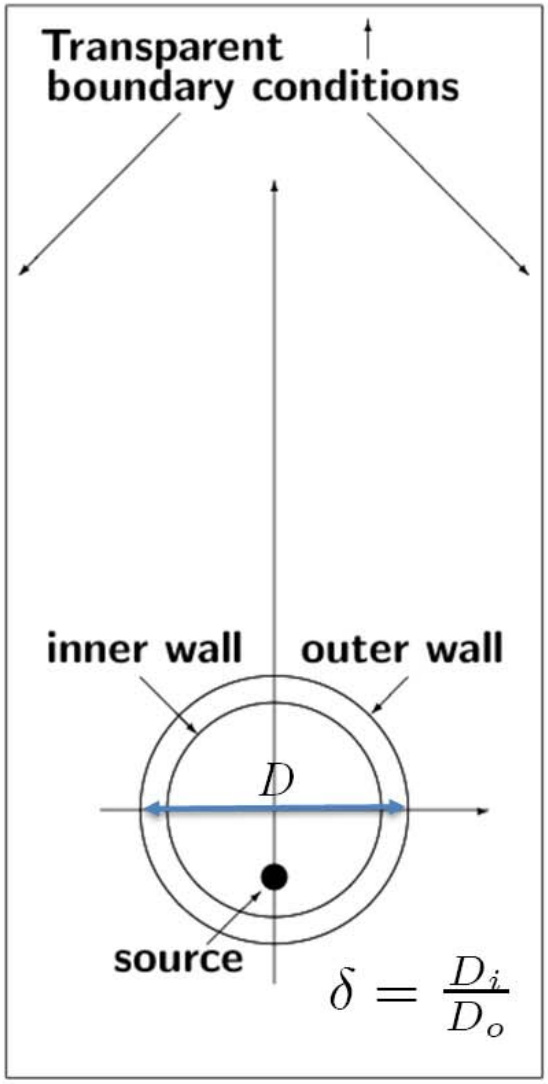
	Typical fabric temperature	T^4	Relative
Earth	353 K	1.55E+10	
Titan	100 K	1.17E+08	0.64%

QUANTIFYING CONVECTION

Two pronged approach:

- Computational modeling/CDF
- Practical validation

Computational Fluid Dynamics Simulations of a Montgolfiere



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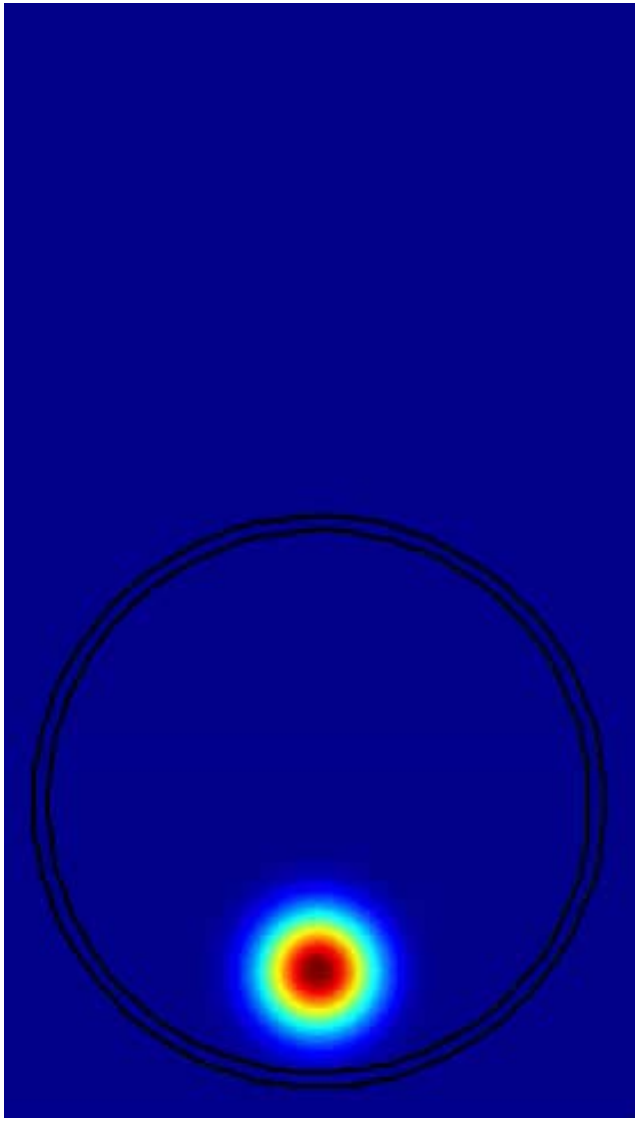
Goals

- Validate and improve heat transfer correlations
- Validate code vs. experiment
- Transient behavior at catastrophic descent
- Evaluate unorthodox designs

CFD model

- Boussinesq flow model (compatible with small temperature differences expected on Titan)
- Fast axisymmetric immersed boundary method
  - ✓Arbitrary geometry
  - ✓No-slip enforced on balloon walls
  - ✓Tethered, ascending or descending

Visualization (temperature contours)



PRELIMINARY RESULTS

- *Flying at Titan temperatures gives very useful practical insights*
- *The CFD model is tentatively validated: more details at COSPAR*
- *The methods developed allowing for much larger Titan simulators, useful well beyond balloons*

Charles Green’s
Great Nassau Balloon

Tibor Balint’s
Great Titan Lakes Balloon